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(54) **ELECTRICALLY-OPERATED ACTUATOR SYSTEM**

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(51) **Int. Cl.**<sup>7</sup> ..... **H02P 3/00**

(52) **U.S. Cl.** ..... **318/479**; 318/466; 318/772;  
318/786; 315/200 A; 315/291

(58) **Field of Search** ..... 318/470-479,  
318/466, 468, 772, 781, 785, 786; 315/200 A,  
291; 303/92, 20

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(57) **ABSTRACT**

A motor stopping circuit is activated when a motor control circuit is stopped by a reset signal outputted from a reset circuit. This maintains an overrun angle small. As a result, a difference between a rotation angles measured when the motor control circuit is turned off and measured when the motor control circuit is turned on are small. Therefore, frequent origin setting operation is not required. This reduces sizes and manufacturing costs of a stopper and an actuator.

**5 Claims, 8 Drawing Sheets**

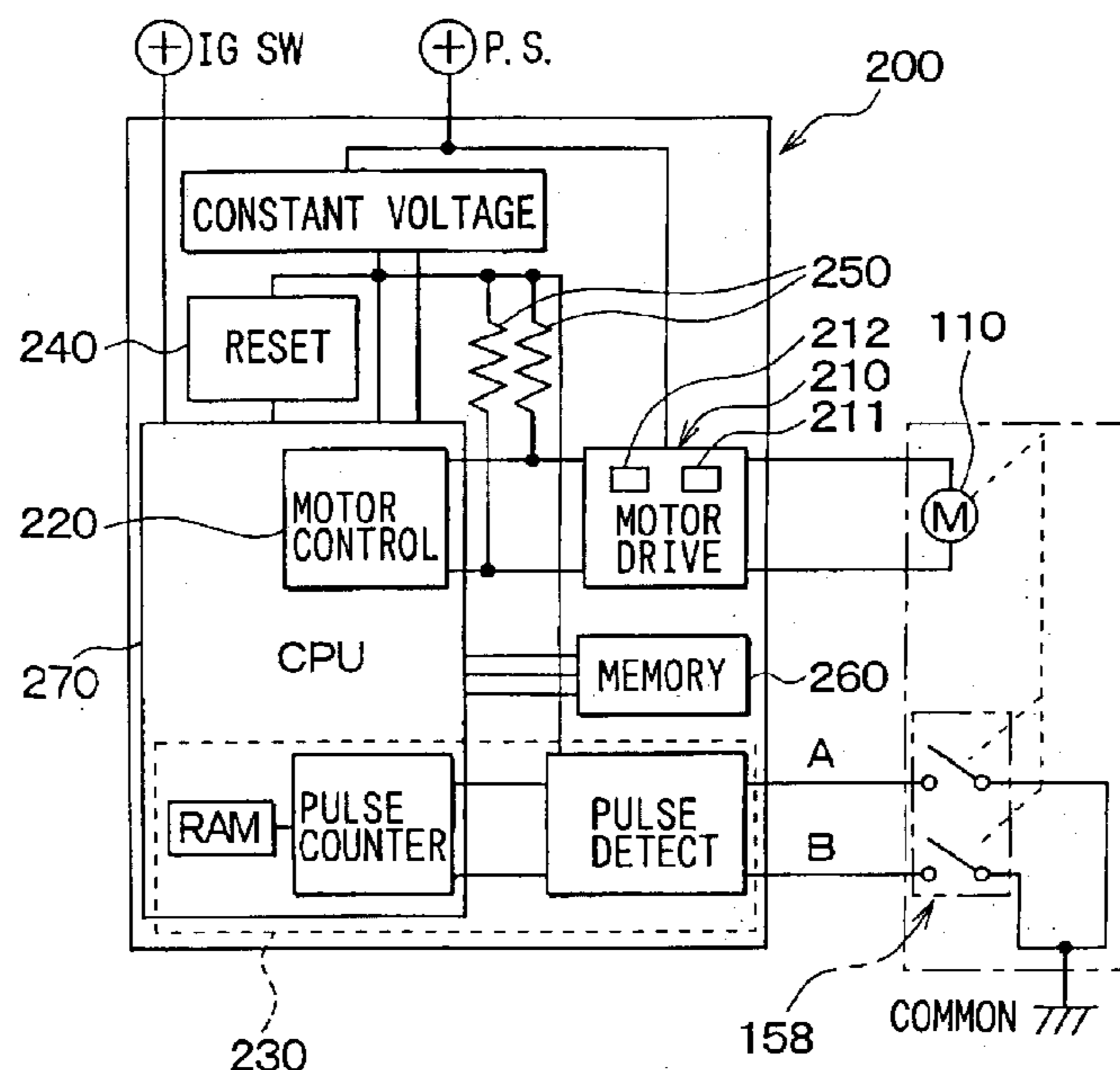


FIG. 1

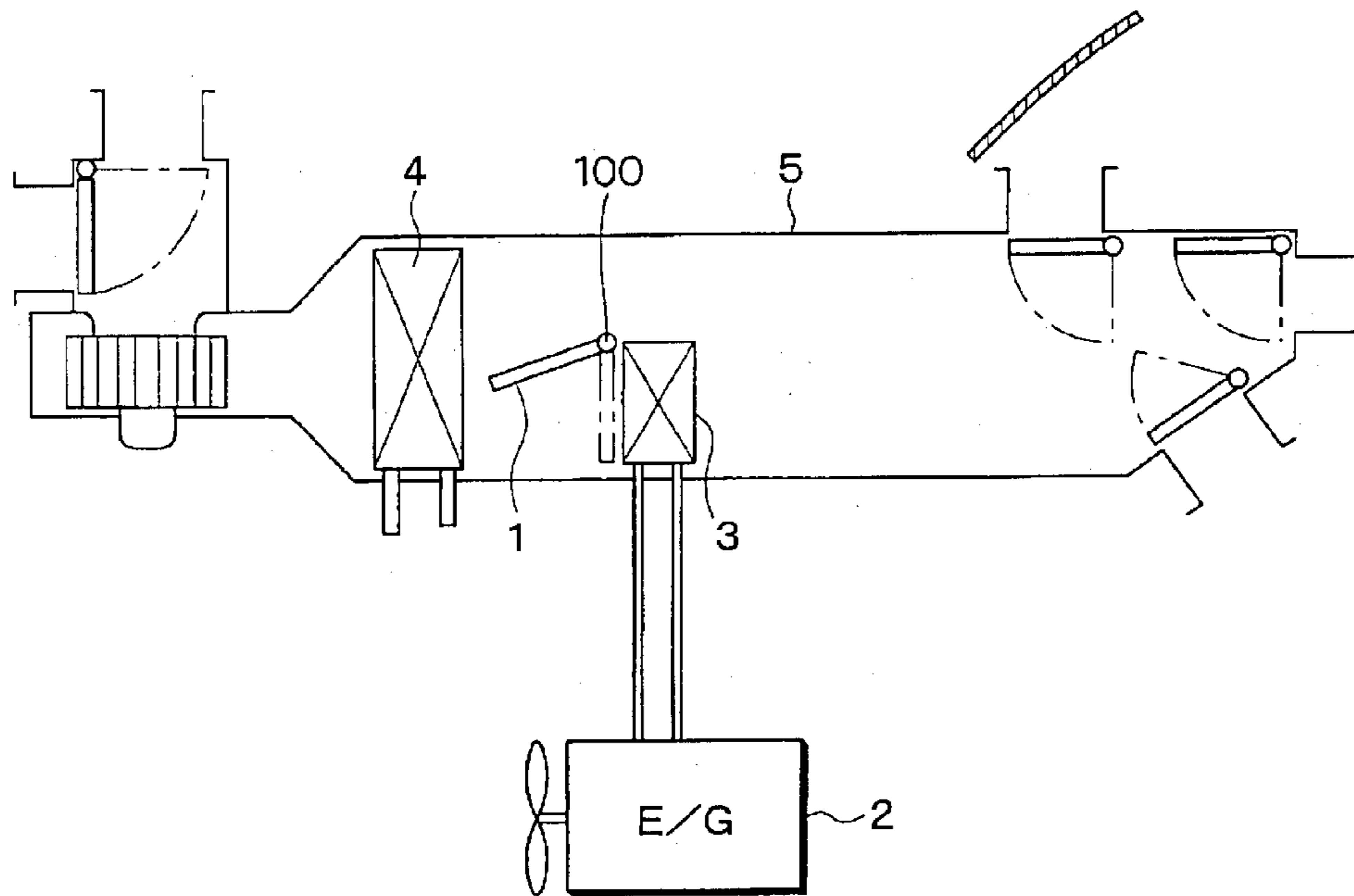


FIG. 2

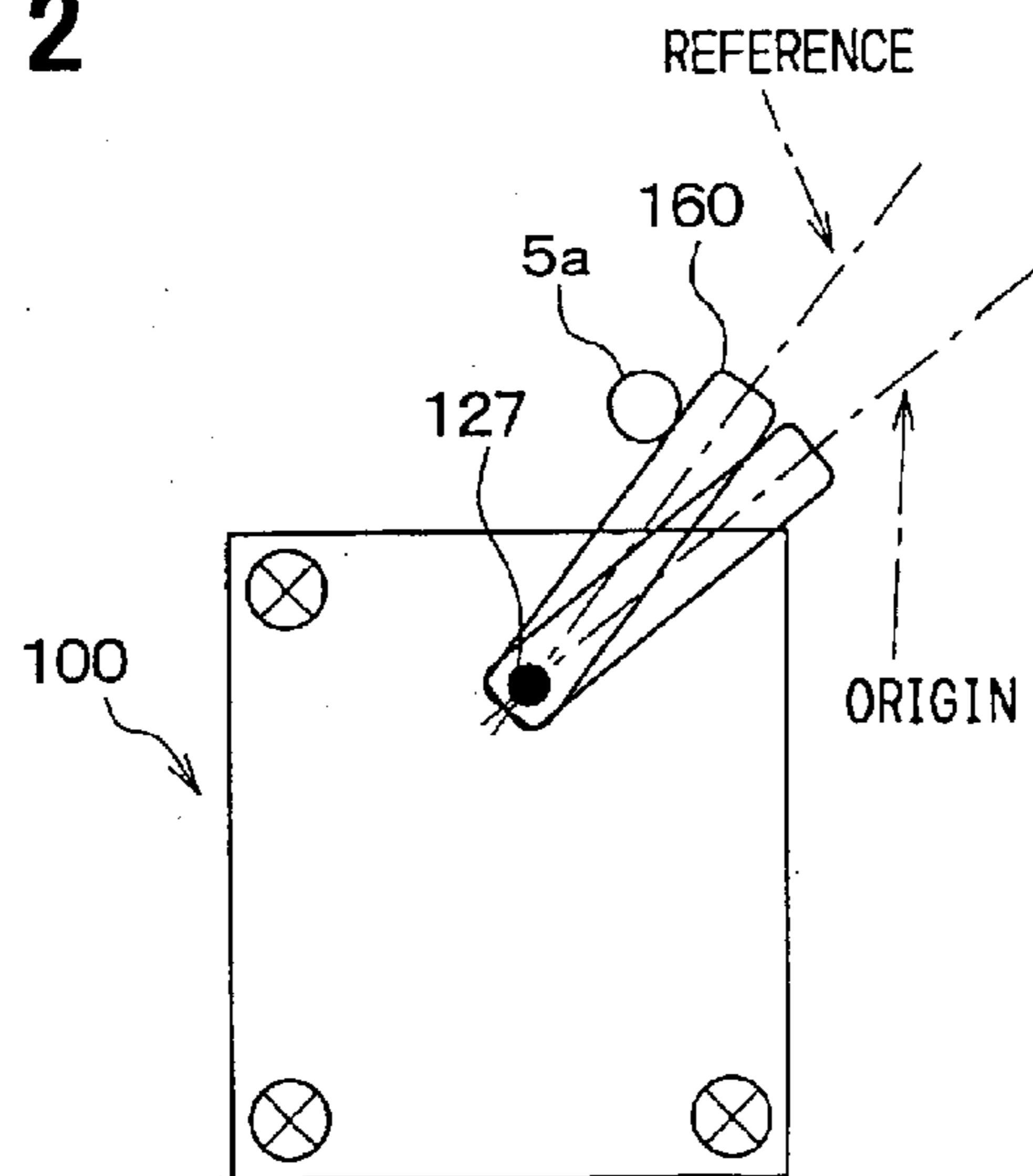


FIG. 3

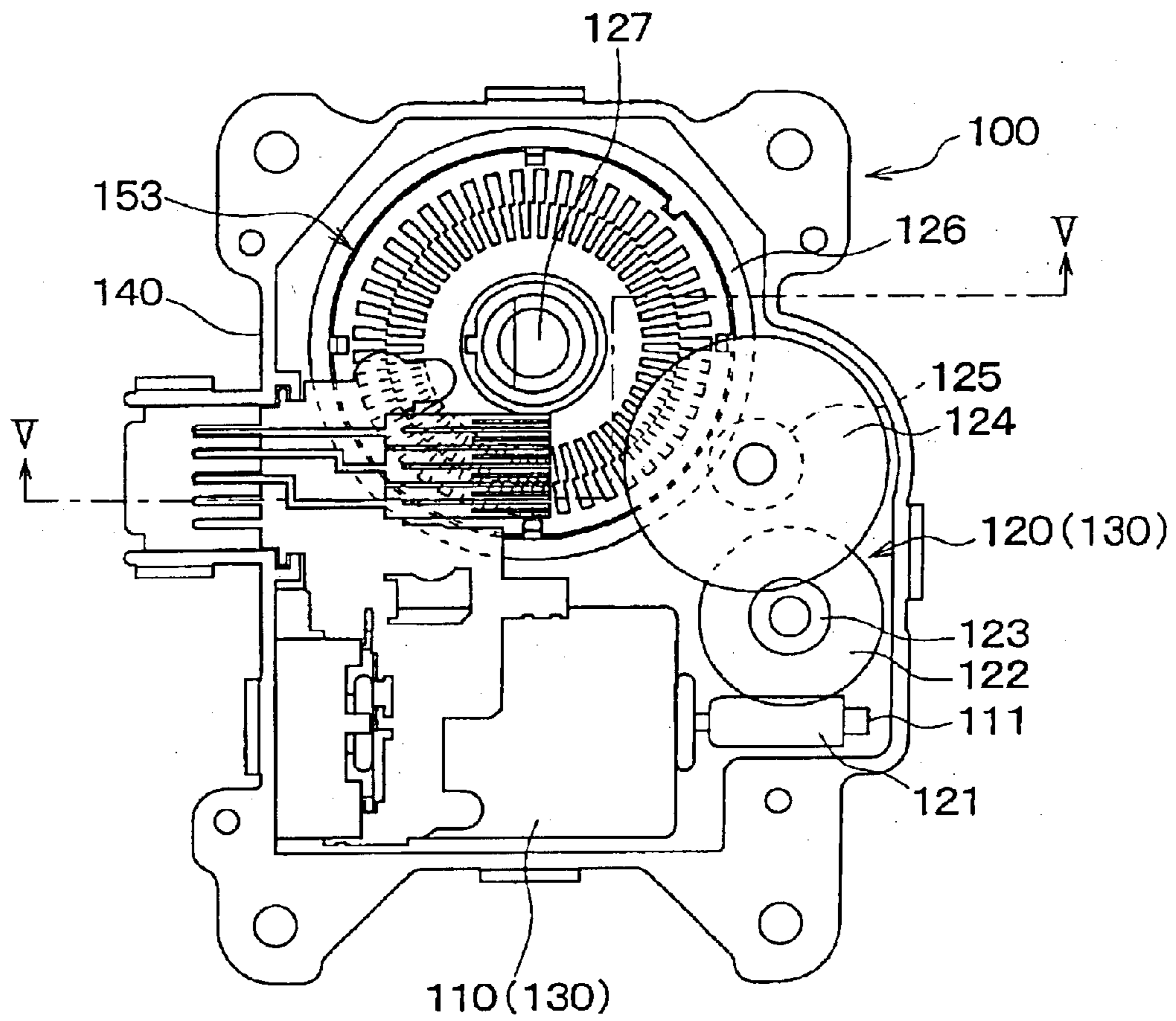


FIG. 4A

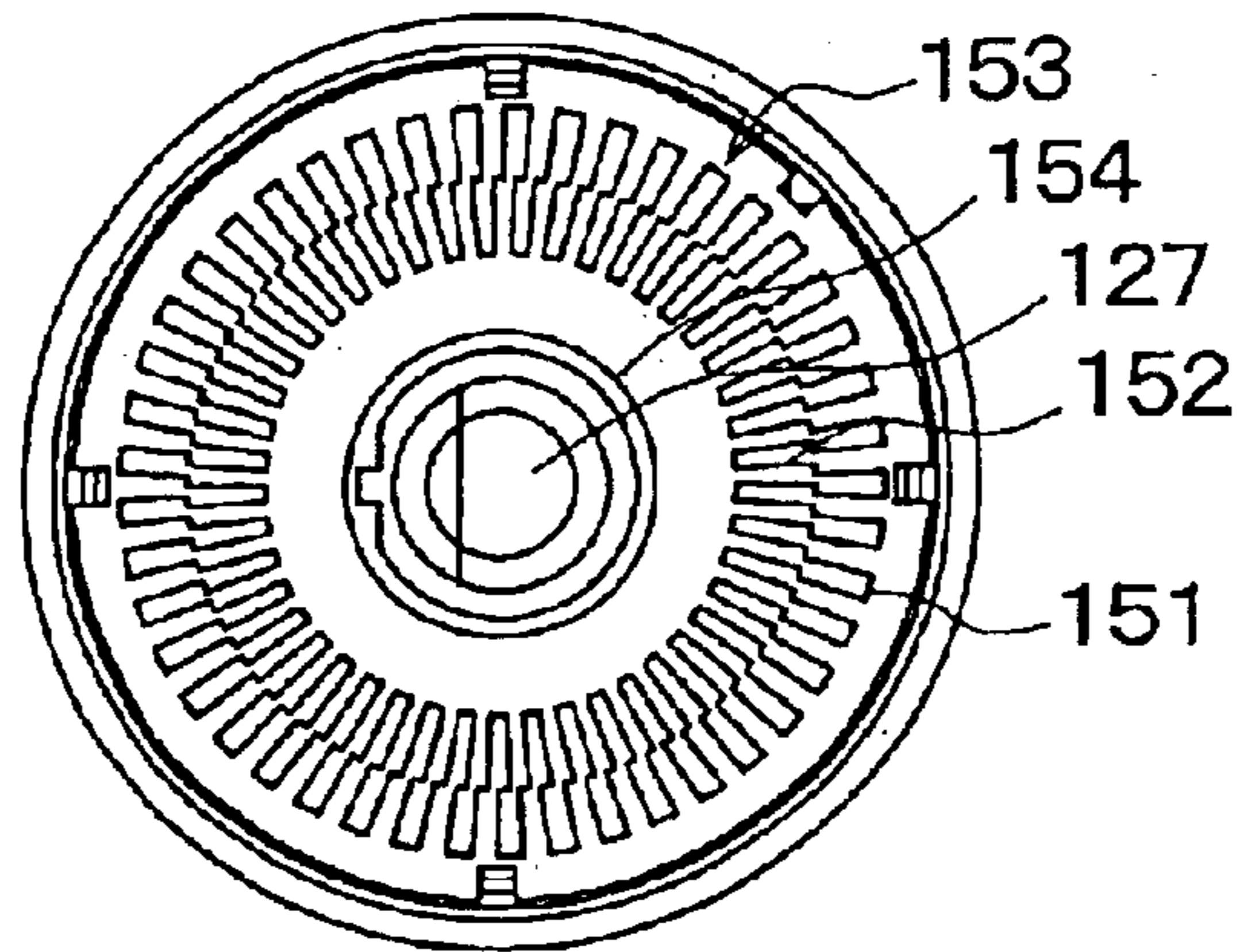


FIG. 4B

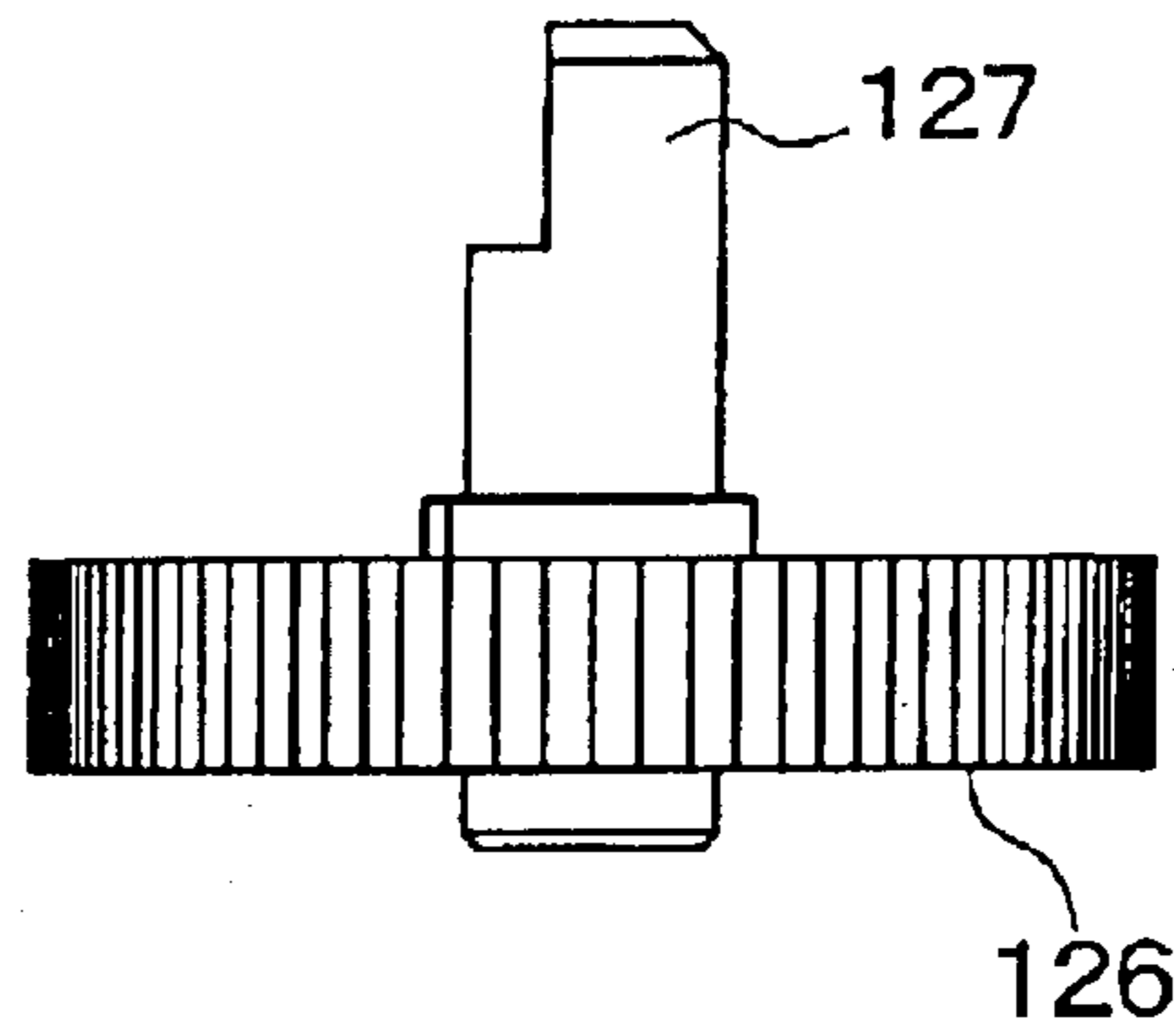
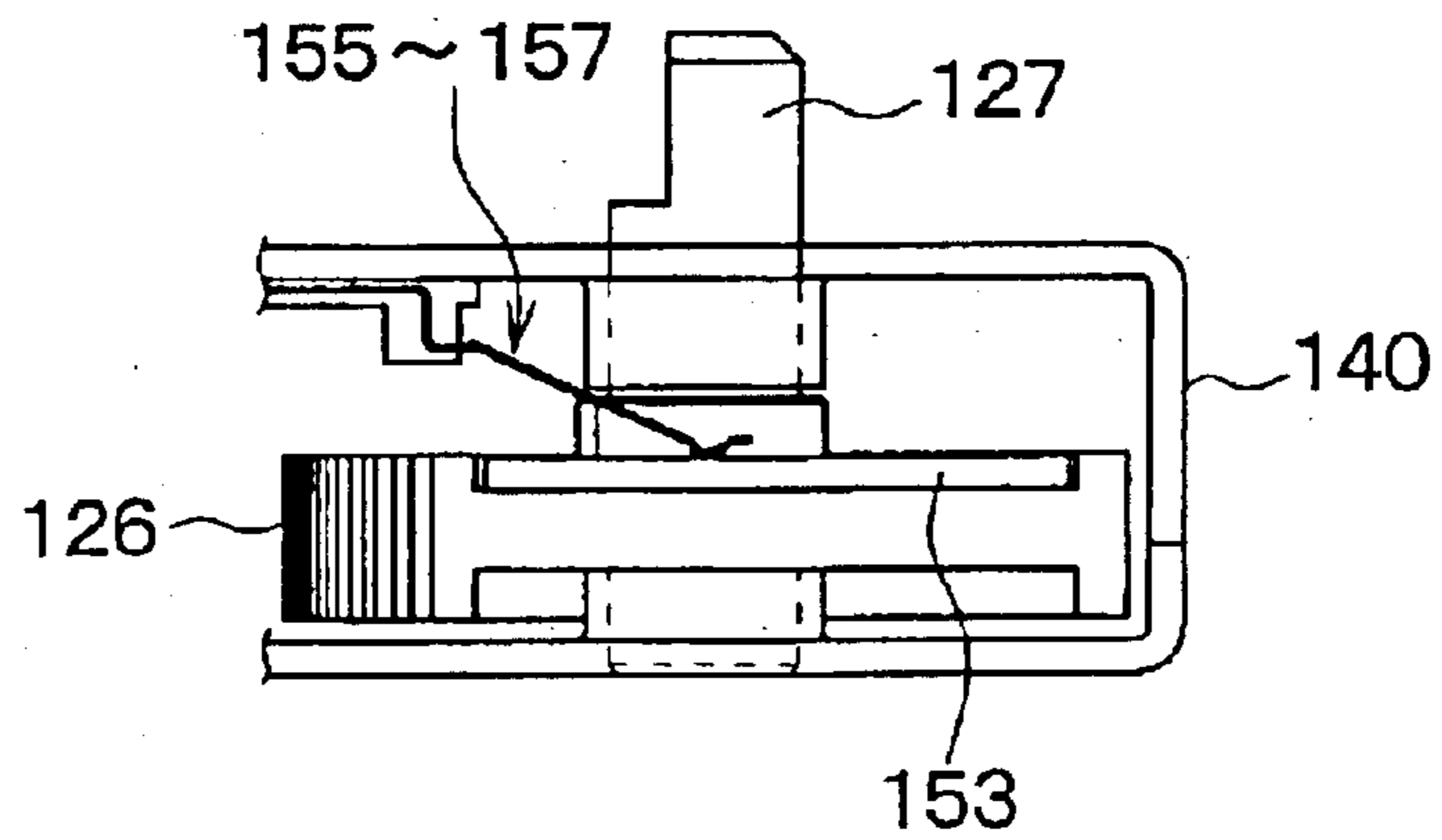


FIG. 5



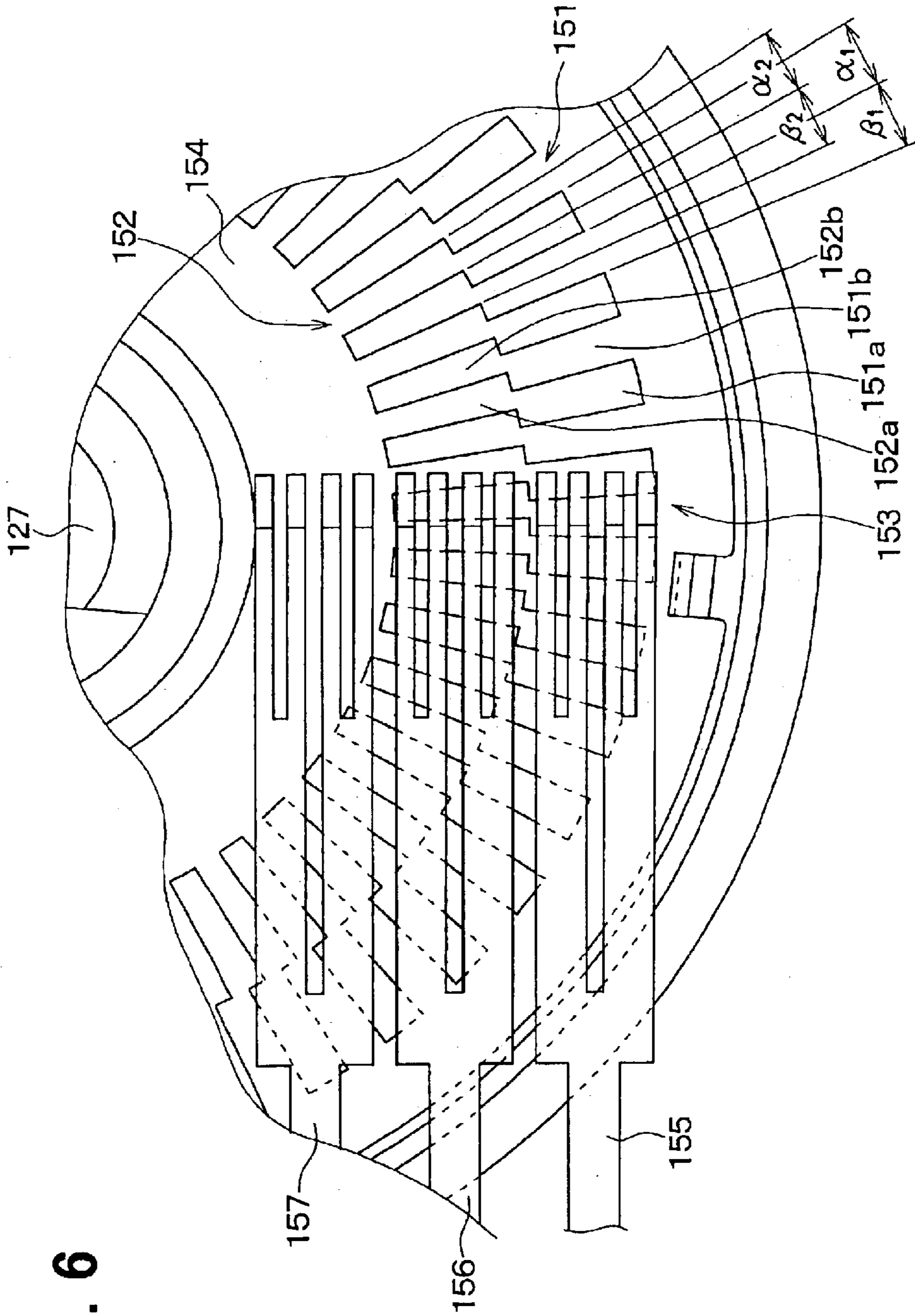


FIG. 6

FIG. 7

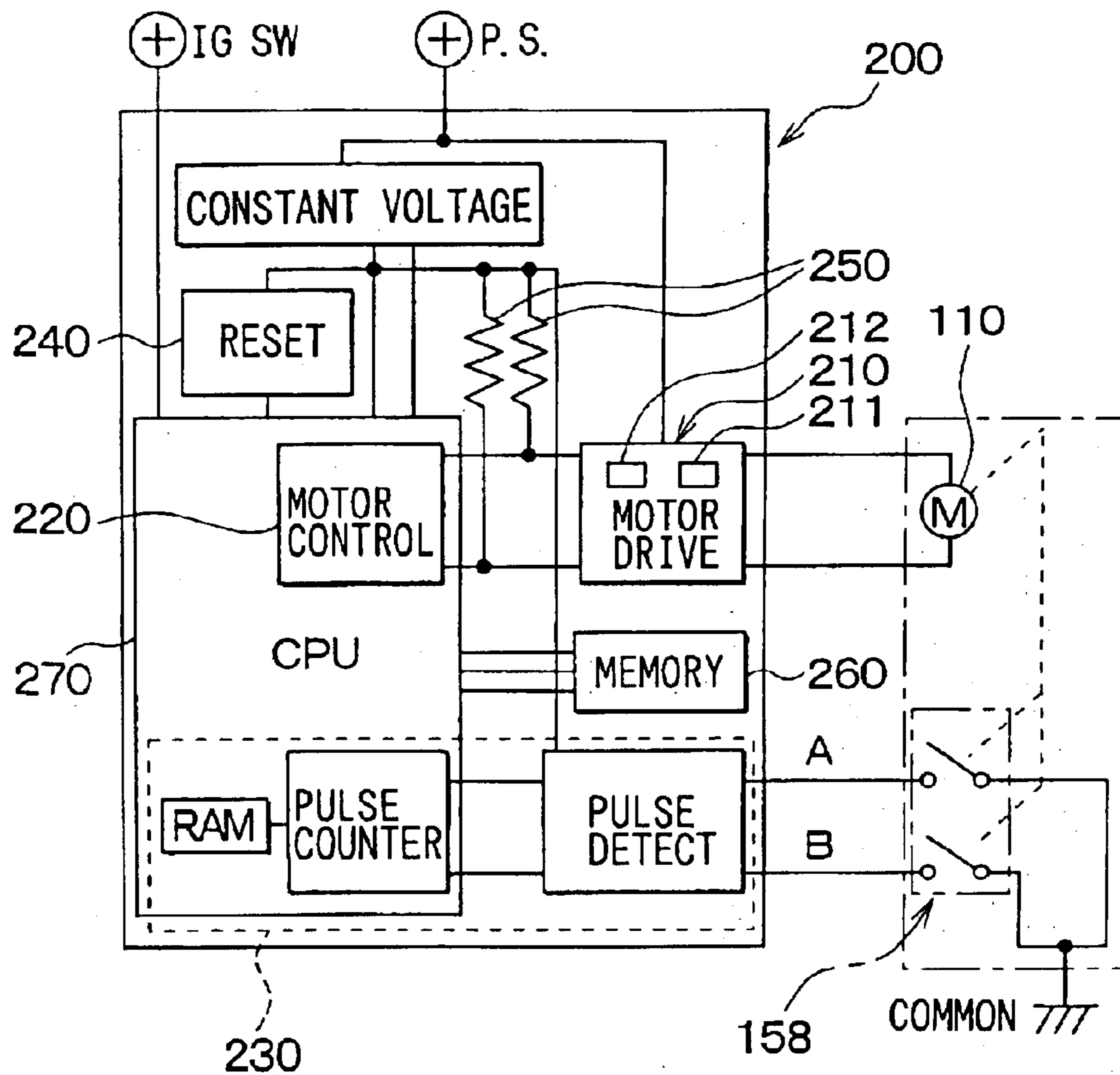


FIG. 8

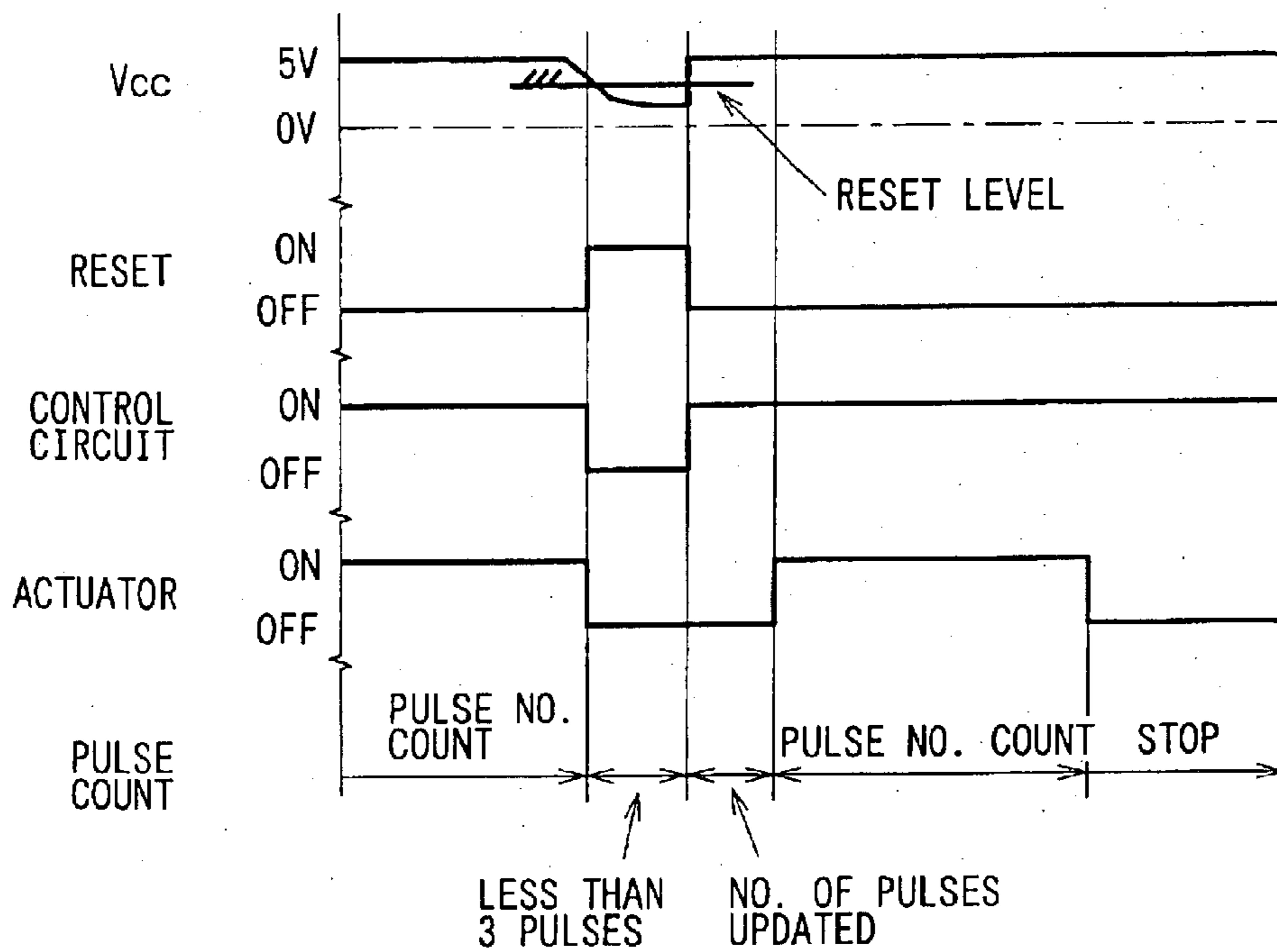


FIG. 9

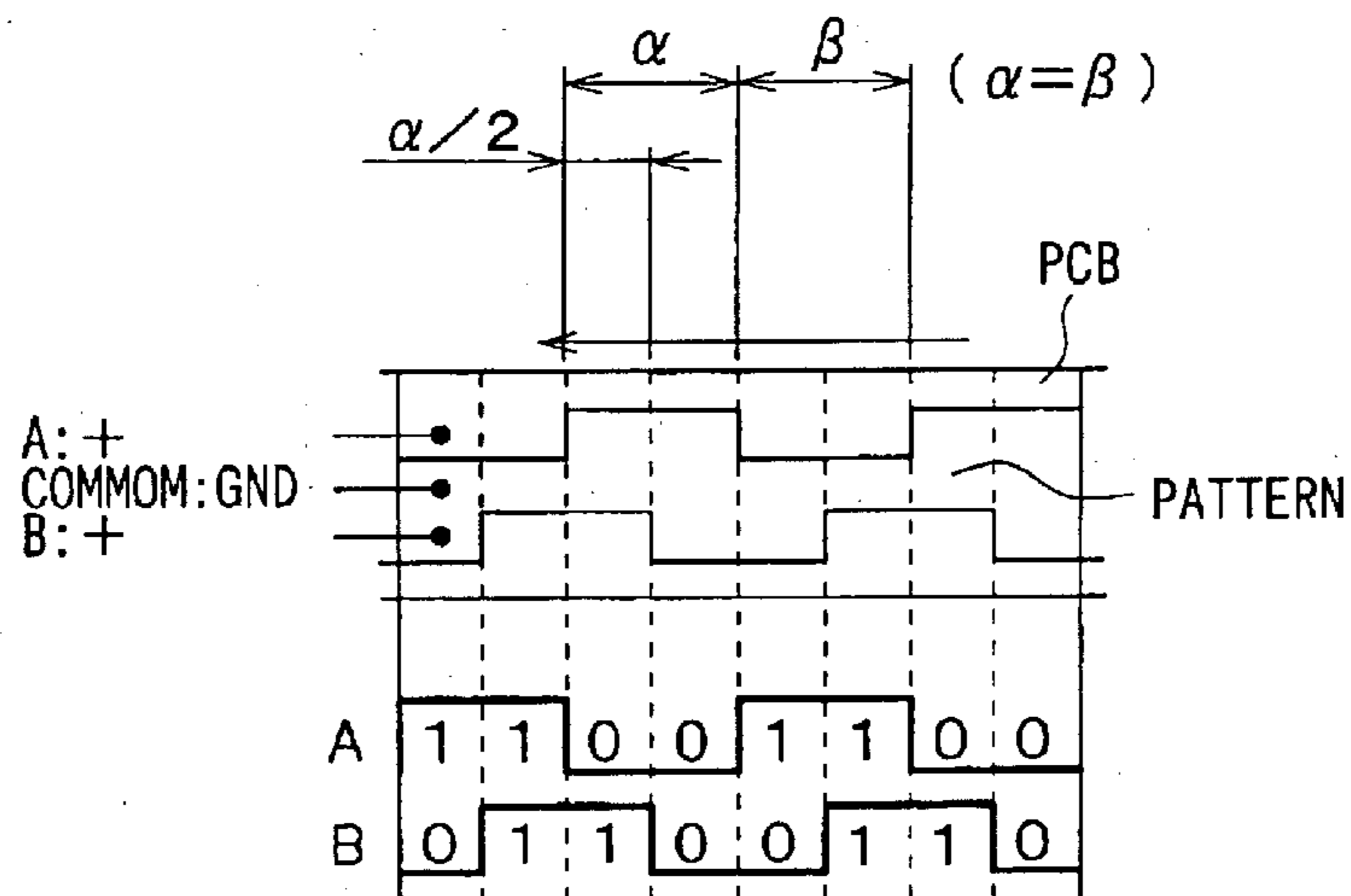
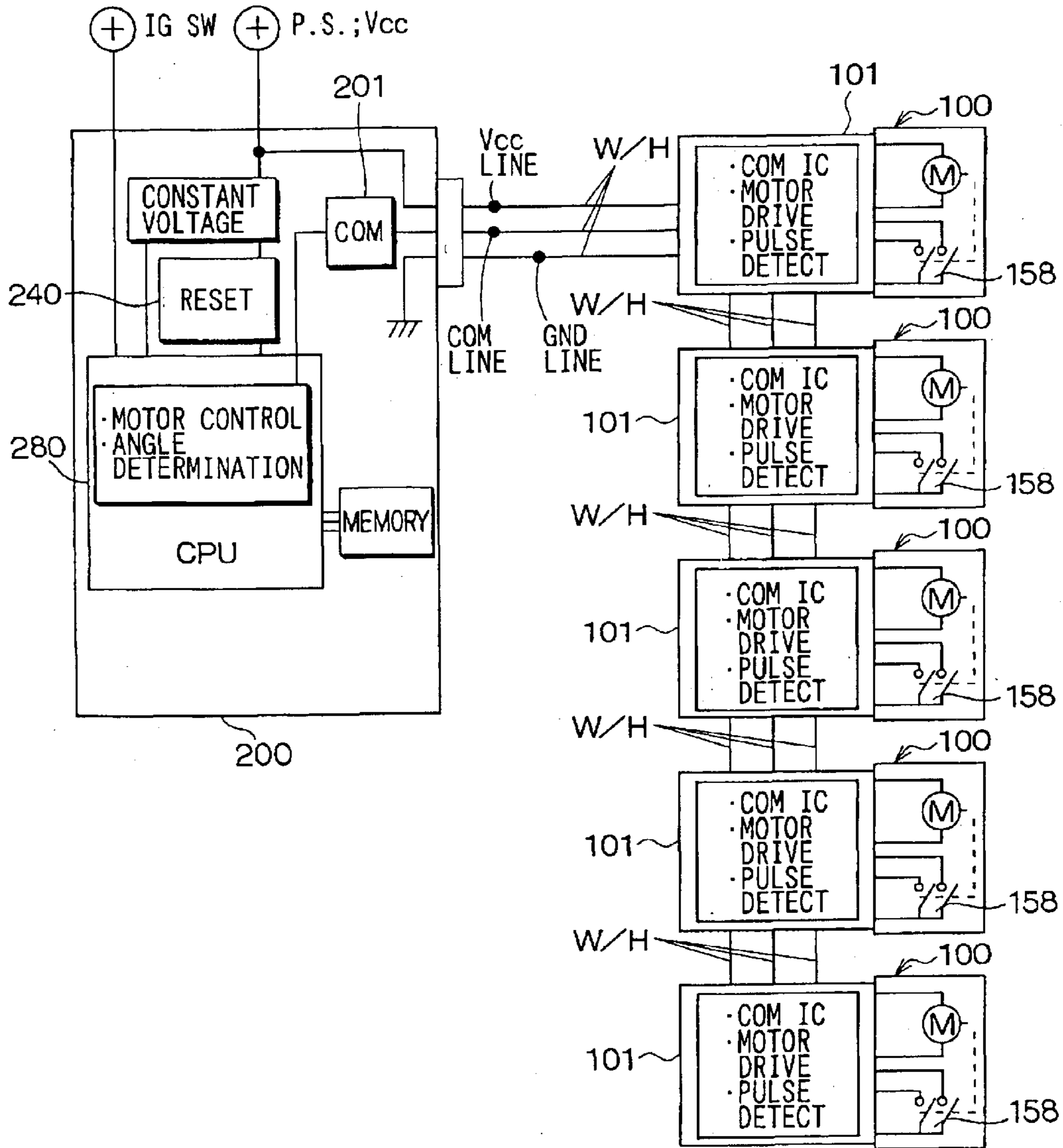


FIG. 10







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## ELECTRICALLY-OPERATED ACTUATOR SYSTEM

### CROSS REFERENCE TO RELATED APPLICATION

This application is based on and incorporates herein by reference Japanese Patent Application No. 2002-194736 filed on Jul. 3, 2002.

### FIELD OF THE INVENTION

The present invention relates to an electrically-operated actuator system.

### BACKGROUND OF THE INVENTION

The applicant of the present invention has suggested an electrically-operated actuator system that uses a pulse encoder for controlling a rotation angle of an electric motor in JP-A-2002-354885. In this system, the rotation angle is controlled based on pulse signals corresponding to the rotation angle. A motor control circuit operates according to control signals produced by a motor control circuit and supplies driving current to the motor.

The inventors of the present invention experimentally added a reset circuit to the actuator system to control operations of the motor control circuit. The reset circuit turns off the motor control circuit when the voltage applied to the circuit becomes lower than a predetermined level. When the voltage becomes higher than the predetermined level again, the reset circuit turns on the motor control circuit.

However, the motor continues rotating for a while due to the moment of inertia after the motor control circuit is turned off. In other words, the motor control circuit is unable to control the motor after the voltage becomes lower than the predetermined level and the motor stops with a large overrun. If the overrun is very large, the amount of motor rotation while the motor control circuit is turned off is not determined nor the amount of the overrun.

In a rotation angle determination process, the rotation angle of the motor is determined based on an angle shifted from a reference position (relative rotation angle). If the reference position is not accurately determined, the amount of motor rotation is not accurately determined. The actuator may be mechanically controlled for bringing it back to the reference position.

The actuator may be driven until it hits a stopper before the restart to bring it back to the reference position. However, the actuator requires a durable structure to resist the mechanical strain. This increases size and manufacturing cost of the actuator.

### SUMMARY OF THE INVENTION

The present invention therefore has an objective to provide an electrically-operated actuator in which an electric motor stops with a small overrun when a motor control circuit is turned off. The present invention has another objective to provide an actuator that does not require frequent origin setting operations.

The actuator of the present invention includes an electric motor, a rotation angle determination means, a motor control means, a reset means, a motor driving means, a motor stopping means, and a motor stopping means driving means. The rotation angle determination means determines a rotation angle of an output shaft of the motor based on pulse signals produced according to a rotation angle of the motor.

The motor control means controls operations of the motor based on the rotation angle determined by the rotation angle

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determination means. The reset means turns off the motor control means when a voltage applied to the motor control means becomes lower than a predetermined level. When the voltage becomes higher than the predetermined level, the reset means turns on the motor control means.

The motor driving means controls driving current supplied to the motor based on control signals from the motor control means. The motor stopping means electrically stops the motor based on control signals from the motor control means. The motor stopping means driving means drives the motor stopping means when the motor control means is turned off by the reset means.

With this configuration, the motor is stopped by electrical breaking. Therefore, the motor is stopped with a small overrun after the motor control means is turned off, that is, an overrun angle is small. Since the rotation angle at the restart is not much different from the angle at the stop, the angle shifted after the motor control means stops is easily determined. The reference position determination is not required upon the restart of the motor. Therefore, the number of the origin setting operations reduces, in other words, the actuator does not require a durable construction. Thus, size and manufacturing cost of the actuator are reduced.

### BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objectives, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. 1 is a schematic view of a vehicular air conditioning system in which an electrically-operated actuator of the first embodiment of the present invention is applied;

FIG. 2 is an external view of the actuator;

FIG. 3 is a plan view of the actuator;

FIG. 4A is a front view of a pulse plate included in the actuator;

FIG. 4B is a side view of the pulse plate;

FIG. 5 is a cross-sectional view of section A—A of the actuator shown in FIG. 3;

FIG. 6 is an enlarged partial view of the pulse plate shown in FIG. 4A;

FIG. 7 is a block diagram of a control circuit of the actuator;

FIG. 8 is a timing chart showing controls of the actuator;

FIG. 9 is a timing chart of pulse signals of the actuator;

FIG. 10 is a block diagram of an actuator system according to the second embodiment of the present invention; and

FIG. 11 is a timing chart showing operations of the actuator system.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiments of the present invention will be explained with reference to the accompanying drawings. In the drawings, the same numerals are used for the same components and devices.

#### First Embodiment

Referring to FIG. 1, an actuator **100** is installed in a vehicular air conditioning system for driving an air mix door **1**. A coolant of an engine **2** is heated by a heater core **3** and the air is warmed up by the heated coolant. The air mix door adjusts the warm air flowing around the heater core **3** to adjust the temperature of the air flowing into the room. An air conditioner casing **5**, which is made of resin, houses the air mix door, the heater core **3**, and an evaporator **4**. The actuator **100** is fixed to the casing **5**.

Detailed configurations of the actuator **100** are shown in FIGS. **2** and **3**. A driving section **130** of the actuator includes a DC motor **110** and a motor speed reduction mechanism **120**. The DC motor **110** rotates with power supplied by an onboard battery (not shown). The motor speed reduction mechanism **120** reduces the rotation speed of the motor output and transmits torque at the reduced speed.

The mechanism **120** is a series of gears including a worm gear **121**, a worm wheel **122**, and spur gears **123**, **124**, **125**. The worm gear **121** is tightly fitted to an output shaft **111** of the motor **110**. The spur gear **125** engages an end gear **126** that has an output shaft **127**. The driving section **130** is housed in a case **140** to which brushes **155** to **157** are fixed.

A pulse pattern plate **153** is provided around the output shaft **127**. The pattern plate **153** includes the first pulse pattern **151** and the second pulse pattern **152**. Each pulse pattern **151**, **152** include conductive portions **151a**, **152a** and non-conductive portions **151b**, **152b**, respectively. The pattern plate **153** rotates with the output shaft **127**.

Inscribed angles  $\alpha_1$ ,  $\alpha_2$  of the conductive portions **151a**, **152a** and inscribed angles  $\beta_1$ ,  $\beta_2$  of the non-conductive portions **151b**, **152b** are approximately equal. A phase of the first pulse pattern **151** differs from that of the second pulse pattern **152** by approximately half of the inscribed angles  $\alpha_1$ ,  $\alpha_2$ . The first and the second pulse patterns **151**, **152** are electrically connected to each other and to a common pattern **154** located closer to the center than the first and the second patterns **151**, **152**. They are all electrically connected to a negative terminal of the battery via the brush **157**.

Three brushes **155** to **157**, made of copper-based conductive materials, are fixed to the case **140** and electrically connected to a positive terminal of the battery. The first brush **155**, the second brush **156**, and the third brush **157** touch the first pattern **151**, the second pattern **152**, and the common pattern, respectively. The brushes **155** to **157** have contacts with conductive portions **151a**, **152a** of the pulse patterns at four points (including the common pattern **154**). As a result, the electrical connections are ensured.

A link lever **160** is tightly fixed to the output shaft **127** for swinging the air mix door **1** as shown in FIG. **2**. The casing **5** has a stopper **5a** for stopping the link lever **160**.

An electric control circuit **200** of the actuator **100** is shown in FIG. **7**. The control circuit **200** includes a motor driving section **210** that has a motor driving circuit **211** and a motor stopping circuit **212**. The motor driving circuit **211** feeds driving current to the DC motor **110** based on an instruction signal from a motor control circuit **220**. The motor stopping circuit **212** supplies stopping current to the DC motor **110**.

The motor control circuit **220** controls the motor driving section **210** by outputting high level (Hi) signals or low level (Lo) signals to the motor driving circuit **211** and the motor stopping circuit **212** via signal lines. The motor stopping circuit **212** starts operating when the signals at both lines are Hi.

A rotation angle determination circuit **230** determines a rotation angle and the direction of the rotation of the output shaft **127** based on pulse signals produced in the pattern plate **153**. A memory circuit **260** stores control information. A memory device that operates without power, such as an EEPROM, is used for the memory circuit **260**.

A reset circuit **240** produces reset signals to turn off the motor control circuit **220** when a voltage applied to the control circuit **220** is lower than a predetermined level. When the voltage becomes higher than the predetermined level, it stops producing the reset signals to turn on the control circuit **220**. The timing of the controls is shown in FIG. **8**.

A pull-up resistor **250** is a motor stopping means driving means for driving the motor stopping circuit **212** by pro-

ducing the Hi signals to the signal lines when the control circuit **220** is turned off. The pull-up resistor **250** has a resistance lower than an impedance of a microcomputer constructed of the control circuit **220** and the angle determination circuit **230** at halt. When the microcomputer stops, the Hi signal is inputted to the control circuit **220** via the pull-up resistor **250**.

Operations of the actuator **100** will be explained below. When the DC motor **110** starts rotating, torque generated by the DC motor **110** is applied to the output shaft **127**. The first and the second brushes **155**, **156** touch the conductive portions **151a**, **152a**, and the non-conductive portions **151b**, **152b** in turn while the output shaft rotates. This changes conducting conditions of the output between a conducting (ON) state and a non-conducting (OFF) state periodically.

The timing chart of the above-described operation is shown in FIG. **9**. Pulse signals appear at the first and the second brushes **155**, **156** as the DC motor rotates for a predetermined angle. The rotation angle of the output shaft **127** is determined by counting the pulse signals by the rotation angle determination circuit **230**. Combinations of zero and one of the pulse signals in phase A and phase B indicates an angle shift from a previous position to the current position. This is only when the current position is shifted within three pulses. Therefore, the motor can be stopped with the rheostatic braking within three pulses.

A pulse generator **158** is constructed of the first and the second brushes **155**, **156**, and the pattern plate **153**. The pulse generator **158** outputs a pulse signal as the output shaft rotates for the predetermined angle.

Since the first pulse pattern **151** and the second pulse pattern **152** are out of phase, the pulse signals caused by them are also out of phase. The pulse signals produced by the first pattern **151** and the first brush **155** has phase A, and the pulse signals produced by the second pattern **152** and the second brush **156** has phase B. The direction of rotation of the DC motor **110** is determined based on which phase, A or B, is inputted to the rotation angle determination circuit **230**.

The DC motor **110** is mechanically stopped when the link lever **160** hits the stopper **5a**. The position at which the DC motor **110** is mechanically stopped is stored as a reference position. When controlling the amount of rotation of the motor **110**, that is, the amount of rotation of the output shaft **127**, a position two pulses from the reference position is set as an origin. This process is referred to as an origin setting operation. This position is not set as the origin when the battery is disconnected or abnormal pulse signals are produced. It is determined that the link lever **160** hits the stopper **5a** when the level of the pulse signals stops changing.

Referring to FIG. **8**, a reset signal is outputted from the reset circuit when the output of the constant voltage circuit becomes lower than a reset level. When the control circuit **220** is turned off based on the reset signal, the motor stopping circuit **212** is activated to electrically stop the motor **110** by shorting an armature of the motor **110**. As a result, the overrun angle remains small.

A difference in rotation angles between the stop and the restart of the control circuit **220** is small. The position of the actuator **100** can be confirmed via the pulse signal detecting circuit. This reduces the number of times when the origin setting operation is required. Furthermore, the sizes and the manufacturing cost of the stopper **5a** and the actuator **100** remain at low.

The motor stopping circuit **212** is required to produce a stopping force to stop the motor **110** within three pulses after the Hi signal is inputted via the pull-up resistor **250**. That is, the number of pulses counted after the motor stopping circuit is turned off should be less than three pulses. The overrun angle cannot be reduced to zero degree. A condition

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of the pulse signal when the motor control circuit **220** is tuned off and the number of the pluses are stored in the memory circuit **260** or a RAM. The CPU updates rotation angle information stored in the angle determination circuit **230** based on the stored pulse condition and the pulse condition when the control circuit **220** is turned on. This improves an accuracy of the control performed by the actuator **100**.

The pulse signals upon the restart are accurately detected by driving the motor stopping circuit **212** based on the control signal from the motor control circuit **220** for a predetermined period after the restart.

#### Second Embodiment

Referring to FIG. **10**, an actuator system includes multiple actuators **100** and a control device **200** connected via a multiplex communication network. This configuration requires less electrical wiring. The CPU and each actuator **100** exchange data signals to control the actuator **100** according to a predetermined protocol and data signals on the number of pulses via communication lines. The actuator **100** operates based on the data signals.

Each connector **101** includes an integrated circuit (IC) for communication, a motor driving circuit, and a pulse detecting circuit. The connectors **101** and the control circuit are connected via wire harnesses W/H that include power supply (Vcc) lines, communication lines, and ground (GND) lines.

Conditions of a power supply voltage Vcc, a voltage of the communication line (COM V), operations of the IC (COM IC) are shown in FIG. **11**. The IC starts operating when the voltage Vcc reaches a threshold voltage. A reset signal is inputted from the reset circuit **240** to the CPU when the voltage Vcc becomes lower than a predetermined level. When the CPU is reset according to the reset signal, Hi signals are outputted from a communication circuit **201** to the communication line. If the Hi signals continue to be outputted for a predetermined period (t1), the IC determines that a failure condition occurs in the CPU. The IC stops the motor via rheostatic braking. A motor stopping circuit **212** is included in the IC or the motor driving circuit **211**.

When the CPU is restarted, frame signals (F1, F2, . . . Fn) corresponding each actuator **100** are inputted to the IC. The IC determines that the CPU or the motor control section operates properly and determines an amount of overrun angle by reading a condition of a pulse encoder.

When the frame signals are not inputted and the signal at the communication line remains Hi for a predetermined period (t2), the IC determines that a failure condition occurs in the CPU. Then, it stops the motor **110** via rheostatic braking.

The present invention should not be limited to the embodiment previously discussed and shown in the figures, but may be implemented in various ways without departing from the spirit of the invention. For example, the reference position may be uses as the origin. The motor stopping circuit **212** may be stopped.

The present invention may be applied to devices other than vehicular air conditioning system and to other types of angle detecting devices such as an optical encoder. The pulse generators **158** (pulse plates **153**) may be provided in a different configuration. Additional rotating sections that rotate at lower speed for generating pulse signals may be provided.

The pattern plates **153** may be constructed by plating gears of the speed reduction mechanism **120** with a conductive member, or by pressing a metal plate. The common

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pattern **154** may be arranged at an outer position than the pulse patterns **151**, **152**, or between the pulse patterns **151**, **152**. When the Hi signals are inputted via the pull-up resistor **250**, the motor **110** may be stopped within two-pulse period and back lash of the speed reduction gear may be detected for a one pulse.

What is claimed is:

**1.** An electric actuator system comprising:  
an electric motor having an output shaft;

a rotation angle determination means that detects a rotation angle of the output shaft based on a pulse signal produced by a pulse generator according to a rotation angle of the electric motor;

a motor control means that controls an operation of the electric motor based on the rotation angle determined by the rotation angle determination means;

a reset means that turns off the motor control means when a voltage applied to the motor control means becomes lower than a predetermined level, and turns on the motor control means when the voltage becomes higher than the predetermined level;

a motor driving means that supplies driving current to the electric motor based on a control signal from the motor control means;

a motor stopping means that stops the electric motor via electric braking based on the control signal from the motor control means within a time that pulses counted after the motor control means is turned off is less than a predetermined number; and

a motor stopping means driving means that drives the motor stopping means when the motor control means is turned off by the reset means.

**2.** The actuator system according to claim **1**, further comprising a memory data revising means that revises memory data on a rotation angle based on a pulse signal at a time when the motor control means is turned on by the reset means.

**3.** The actuator system according to claim **2**, wherein the motor stopping means is activated based on a control signal from the motor control means for a predetermined period after the motor control means is turned on.

**4.** The actuator system according to claim **1**, wherein:

the motor control means controls the motor stopping means by outputting high level and low level signals to two signal lines that are connected to the motor stopping means;

the motor stopping means is activated when the signals at both signal lines are high levels; and

the motor stopping means driving means outputs the high level signal to each signal line.

**5.** The actuator system according to claim **1**, wherein:

a plurality of connectors and actuators are provided

the electric motor, the pulse generator, the rotation angle determination means, the motor driving means, and the motor stopping means are integrated as a connector and a actuator;

the motor control means, the reset means, and the motor stopping means driving means are integrated in an electric control means; and

the electric control means is connected with the connectors via wire harnesses for multiplex communication.